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Level Matching for Autosound . . . or Why is my system so noisy?

by

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Level Matching for Autosound . . . or Why is my system so noisy?

Introduction

With the advent of really high-performance automotive sound systems, the old problem of noise (in its various forms) has once more raised its ugly head. Even if the manufacturer has done their engineering homework, it's still really easy to forget some detail during installation and make even the quietest components seem noisy.

Consider:

- A head unit with an integral power amplifier.
- An outboard equalizer, with input and output level controls.
- An outboard power amplifier, with high- and low-level inputs.

What we have here is a potential disaster. If the level adjustments between the various components aren't made correctly, the finished system could be any of the following:

- Noisy
- Distorted
- Seemingly under powered

In this guide, we'll discuss some of the causes of noise in audio systems and explore some ways of dealing with them. Along the way, we'll also cover the interface problem listed above. At times, this guide may seem a bit long-winded. It is, but the risk of spreading misinformation by oversimplification is quite high so do yourself a favor and stick with us; the time you spend reading this will be well spent.

What is noise?

In any audio system, there are several potential noise sources.

- thermal noise
- induced noise
- noise caused by a ground loop

Thermal Noise

Thermal noise sounds like the hiss that you hear between stations on your FM radio. Thermal noise occurs because mankind chooses to live at 300 degrees above absolute zero. Thermal noise occurs because of the random movement of electrons caused by thermal agitation. At absolute zero, thermal agitation ceases to exist. Unfortunately, we haven't found a way around this problem yet.

Just because we live at temperatures other than absolute zero doesn't mean that we can't deal with thermal noise. Careful design, along with attention to detail can minimize this type of noise. Remember...the word is minimize not eliminate.

Induced Noise

Induced noise has a variety of causes. Induced noise is sneaky. Sometimes it gets into your system through the power wiring, other times, it may sneak in via two adjacent wires. Still other times, it just gets in through the air.

Although a car is powered by a battery, (and everyone knows that batteries put out pure DC) the automobile electrical system is one of the nastiest environments known to electronic equipment. The alternator, which generates power to recharge the battery while the engine is running, puts high-current pulsating DC into the battery, which shows up everywhere else in the electrical system. Alternator noise sounds like a whine whose pitch is proportional to engine speed.

The alternator wiring carries fairly high currents, even though the voltage is relatively low. Passing an electrical current through a wire is a sure-fire way to generate a magnetic field. Higher currents generate higher strength fields. Now, if you put two wires in close proximity to each other, and one of them is carrying an electric current, you can generate electricity in the other by one of two methods:

1. Move one of the wires relative to the other.
2. Vary the electric field.

Since the alternator puts out alternating current method two applies here. This is the very same principle that a transformer (not the guys on Saturday morning TV) uses. Imagine what could happen if the other wire was the lead from the head unit to the power amplifier.

The last cause of induced noise is electromagnetic interference (EMI). This is the same method that radio transmitters use. Basically, the sound system's wiring becomes an antenna, and the amplifiers within the system become the receiver. Unfortunately you don't want to listen to the interfering station. Some examples of EMI are ignition noise or perhaps the loud buzz that you hear if you drive near a television transmitter.

Ground Loops

Ground loops are insidious. They are caused by the non-zero resistance of the wire used to interconnect the equipment. Typically, ground loops are created by a piece of equipment having multiple connections into the grounding system.

In autosound, this problem is exacerbated by the rather callous belief by auto makers and certain other folks that the metal frame of the vehicle makes a good ground. While this may be true for cigarette lighters and tail lights, applying this belief to audio systems is a gilt-edged invitation to disaster.

Figure 1 shows what happens. Generally, the audio wiring has higher resistance than the power wiring. Since the electrical system of the car uses the body/frame structure as its negative return, the non-zero (yes, it's small, but not small enough!) resistance of the car body allows small voltage drops to be created between various points in the car body.

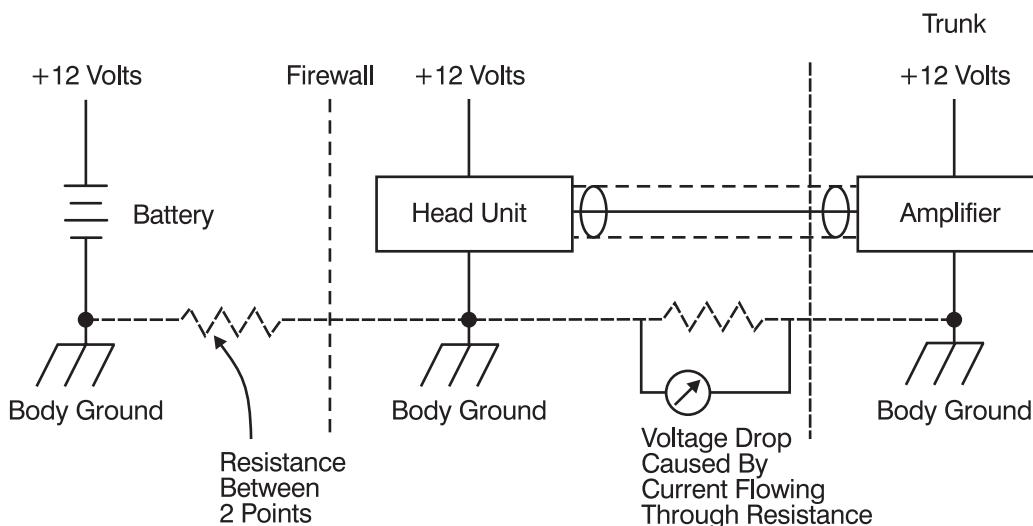


Figure 1. Anatomy of a ground loop.

The alternator in the battery charging system makes things worse because the frequency of its AC output (alternating current...that's why it's called an alternator, not a generator) is easily within the audible range. The low impedances involved (high available current means low impedances) make filtering out alternator noise even more difficult. Anyway, these voltage drops occurring between various points in the car body usually have alternator noise riding on them, which gets into a sound system via a ground loop.

Until you've traced out a noise problem, and found it to be a cleverly concealed ground loop, the phrase "**ground isn't Ground**" just sounds like random noise from another audio fanatic. All it takes is one good ground loop problem to turn the hardiest skeptic into a believer.

The Meaning of Signal-to-Noise Ratio

Signal-to-noise ratio is a common term used on spec sheets. As common as it is, many people (both learned and not) misunderstand or misuse it. Signal-to-noise ratio is the relationship between a device's normal operating level, the noise floor, and peak clipping.

The noise floor, or the Ultimate noise

All electronic equipment operating above absolute zero generates noise. Fortunately, modern electronic design techniques can identify each noise source, all the way from the tape head in a cassette machine, to each stage in the amplifiers following it on the way to the speakers. Careful design minimizes each potential source, resulting in optimum performance. Of course, cost is a limiting factor in the overall design process at least if most of us are to be able to purchase the device. The bottom line is the thermal noise generated by the electrical resistance of the source. In the case of a cassette machine, the source is the tape head itself. Even if the amplifiers following it were noiseless, they would still amplify the thermal noise of the head itself. This then is the Ultimate noise.

The normal, residual noise output of any electronic device is known as its noise floor. Again, it is the product of the thermal noise of the source, plus the noise contributions of each succeeding amplifier stage.

Peak clipping, or the peak ceiling

At the other end of the scale is peak clipping. Peak clipping occurs when an amplifier's output signal can no longer rise as directed by the input signal. Typically, it occurs when the peak value of the output signal attempts to exceed the value of the power supply voltages supplied to the amplifier stage.

Figure 2 shows this graphically. The amplifier supply voltages are + and - 12 volts. The signal can vary around ground (zero volts), up to 12 volts positive (above ground) or 12 volts negative (below ground). If the signal were to try to exceed this limit, clipping occurs once the instantaneous signal level reaches 12 volts. At this time, the output can go no further, and the signal peak is truncated or flattened until the signal level falls below 12 volts. The signal level at which clipping occurs is known as the peak ceiling.

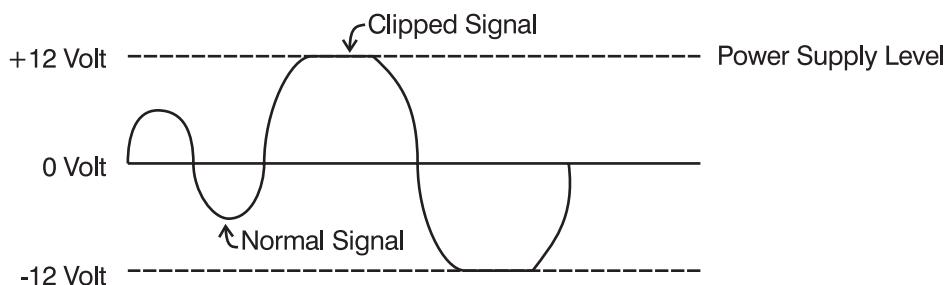


Figure 2. Clipping.

Operating level, headroom, and signal-to-noise ratio

Somewhere between the noise floor and peak clipping is the normal operating level of a device. Looking at this relationship graphically (Figure 3), the distance (difference) between operating level and the noise floor is known as the working signal-to-noise ratio. Finally, the distance between peak clipping and the noise floor is known as the dynamic range.

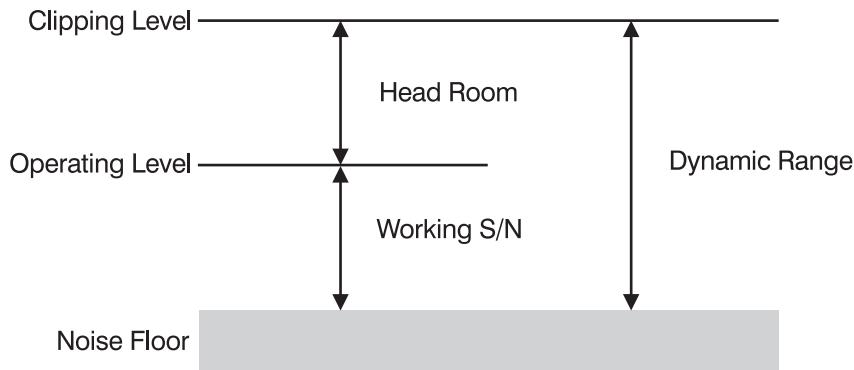


Figure 3. The relationship between operating level, clipping and the noise floor.

As you can see, the operating level chosen for any given device has a pretty direct effect on the working signal-to-noise ratio. Pick a level that is too high and you get premature peak clipping (but spectacular noise performance). Pick a level that is too low and you have lots of headroom, but a poor working signal-to-noise ratio. Let's put some numbers on this: a hypothetical unit, with a -70dB noise floor, and a +10 dB clipping level.

Right off, you can see that there is a maximum dynamic range of 80 dB (+10 - -70). Now, let's explore a few different operating levels. First, we'll used -20 dB which corresponds to a signal level of around 0.1 volt. At -20 dB, the working signal-to-noise ratio is 50 dB (-70 - -20), which is okay, but not spectacular. At this same level, we have 30 dB of headroom (+10 - -20).

Now let's push the operating level up to -10 dB, about 0.3 volt. See if you can do the math yourself. The working signal-to-noise ratio is 60 dB and we have 20 dB of headroom. As you can see, there is always a tradeoff between signal-to-noise and headroom. For our make-believe unit, this would be a good level to operate it at.

Some manufacturers have been known to specify the dynamic range as the signal-to-noise ratio. For the unwary person who only looks at numbers without really understanding them, this gives a truly spectacular number. Only under the most optimistic of operating conditions could the dynamic range of a device be construed as the signal-to-noise ratio. The condition under which this is true is where the headroom remaining is precisely zero dB.

The optimum operating level is a compromise between headroom and working signal-to-noise (s/n) ratio. For most systems, 60 to 80 dB of working s/n is adequate and practical. Likewise, there should be at least 16 dB of headroom to accommodate signal peaks. Picking the right operating level for each component in the system allows you to set the working signal-to-noise ratio/headroom tradeoff.

Gain, Level, Sensitivity, and Power Relationships

Another source of error is the interrelationship between gain, signal level, sensitivity, and output power. First some definitions:

Gain Generally this is shorthand for voltage gain. A measure of the amplification factor of an amplifier, or the output voltage divided by the input voltage. Thus, 10 volts out for 1 volt in is a gain of 10. Sometimes gain figures are converted into decibels (dB). In this case, a voltage gain of 10 converts to a voltage gain of 20 dB. It's handy to use decibels for gain calculations because the only math you need is simple addition and subtraction (once you do the decibel conversion).

Signal Level This is the strength of a signal, measured in volts. Again, sometimes signal levels are measured in decibels, which states them as a ratio of two quantities: the signal, and a known reference level. Signal levels are also referred to by their ability to drive an input: line level, speaker level. While the voltage present may be the same, the current (amperage) capability may not be the same. Basically, this is what is different between a 1 volt line level signal and a 1 volt speaker level signal.

Sensitivity This is a measure of the input signal requirement of a device for some stated output level. Sensitivity is intimately related to gain. If an amplifier has a gain of 10, and it's rated output level is 10 volts, then its sensitivity is stated as 1 volt. It's important to remember that low sensitivity means a higher voltage is necessary to drive the unit, while high sensitivity means less voltage is required. Note that sensitivity has nothing to do with power output.

Power Output Power represents energy, which can do work (like moving a loudspeaker cone). Power is always measured in watts. Power has nothing directly in common with sensitivity. It is equally possible to have an amplifier that has low sensitivity, but high power output as well as one that has high sensitivity, but low power output.

The old volume control myth

A common old wives tale is the belief that the percentage rotation of the volume control represents the same percentage of output power. Here's the way it goes: "I've got so much power that I only need to turn up the volume to 10 o'clock (20% rotation)". Since the volume control generally adjusts the overall gain of the system, there is one unique signal level where wide open (100% rotation) represents full power output from the power amplifier. Since most volume controls are followed by gain (to make interfacing varied signal sources easier), the average system reaches full power long before 100% rotation is reached. Thus, the amount of volume control rotation required to drive the system to full output depends on:

1. The signal level present at the input of the volume control.
2. The amount of gain following the volume control.
3. The sensitivity of the power amplifier (better low than high, from a noise standpoint).

Why bother? A good reason is to make sure that the signal going to the power amplifier is as strong as possible. This helps to subjectively reduce noise that may be induced between the head unit and the power amplifier by making the signal in the cable much stronger than the induced noise.

Another reason is to maximize the amount of useable range that the volume control has, which is especially useful with units that have detented (click-stepped) volume controls. The volume control taper (rate-of-change vs. amount of rotation) at the low end of the control is necessarily coarse. After all, most people like to be able to shut the sound off once in a while. A system that is too loud when the control is three clicks from off isn't very useful unless the owner is a hardened volume freak. Remember to explain to the owner than even though the control must be turned "way up", that they are still getting full performance out of the amplifier.

The impedance problem

Another old bugaboo is the "matching" of impedances. Let's put this one to rest right now.

In a contemporary audio system, there is no need to match impedances, except where maximum POWER transfer is desired. Currently, the only place where this is true is at the antenna terminals of a radio receiver.

If we don't match impedances, then what do we do? Simple...make sure that the output impedance of the source is less than the input impedance of it's load. Thus, a head unit with a 1000 (1K0) ohm output impedance is fine driving an amplifier with an input impedance of 10,000 (10K) ohms. On the other hand, a head unit with an output impedance of 10,000 ohms is not okay looking at a power amplifier with an input impedance of 1000 ohms.

Let's take a moment and look at amplifier and speaker "matching." As mentioned previously, the only place where impedance matching is desirable is where you are interested in maximum power transfer. Impedance matching occurs where the actual source impedance equals the actual load impedance (i.e. 8 ohm source, 8 ohm load). For a typical solid-state amplifier, the actual output impedance is perhaps 0.01 ohm. Why do the manufacturers tell us that the amplifier is intended for a 2 ohm load? What they are really telling us is:

This amplifier is suitable for load impedances down to a minimum of 2 ohms.

What would happen if we were to actually try to match impedances, in the strict sense of the word. If the amplifier were perfect (technologically impossible), we'd have a very large power output figure.

For example, let's create a fictitious amplifier that not only has a 0.01 ohm output impedance but can actually drive a 0.01 ohm load (speaker). This amplifier has a 4 ohm power rating of 50 watts. Doing a bit of quick math, this means that the amplifier will develop 14.14 volts across a 4 ohm load. Now if we drop the load (speaker) impedance to 0.01 ohms (remember, we said **matched impedances**) then this amplifier will deliver 20,000 watts of output power, albeit into a 0.01 ohm load. If you're not afraid of the math, the power in the load is the voltage squared, divided by the load impedance. For our hypothetical amplifier:

$$\text{Power} = (14.14 \times 14.14) / 4, \text{ or } 50 \text{ watts.}$$

If you tried this in the real world and the amplifier was well designed, it would do the best it could (basically it would stop at around 50 watts output) and probably get quite hot under the collar. If the amplifier weren't so well designed, then it might destroy itself trying to drive the abnormal load. That's why you can't just keep connecting speakers to an amplifier unless you're trying to help the amplifier repairman buy a BMW.

Minimizing Noise in Autosound Systems

Now that we've established some of the causes of noise in any audio system, let's apply them to a typical autosound system. First let's make some assumptions:

1. The manufacturer did their design homework and the unit represents the best that they could do, considering their design constraints.
2. The unit meets its published specs.

Identifying noise sources

All the noise filtering in the world won't help unless you can identify the various potential noise sources in the system.

Alternator	Sounds like a whine whose pitch varies with engine speed. It can be caused by poor or careless grounding, ground loops, poor wiring practices, or bad level matching. Bypassing the alternator output with a capacitor may help.
Ignition	A ticking sound that changes with engine speed (the clicks get closer together). It can be caused by poor or careless grounding, ground loops, poor wiring practices, or bad level matching. Resistor spark slugs may help, especially when tuners are affected.
Turn Signals	A clicking sound synchronized with the turn signals. Make sure that the auto body ground connections to the lamps are secure. Bypassing the input and/or output to the flasher unit with a capacitor may help. Other possibilities include poor or careless grounding, ground loops, or bad level matching.
Dash Lamp Dimmer	A buzzy whine whose pitch varies with the dimmer setting. Try bypassing the dimmer input lead with a capacitor and/or different grounding points for the autosound system.
Horn	A buzzing sound, synchronized with the horn (how did you guess?). Again, a bypass capacitor should fix this too.

Amplifier Power Supply

High-powered amplifiers sometimes cause problems because the DC to DC converter inside of them radiates EMI (electromagnetic interference) into the electrical system of the car. This type of noise sounds like a nasty buzz, that isn't affected by engine speed and is usually affected by some or all of the system controls. Sometimes (especially when the units are mounted on a board in the trunk) the manufacturer will leave the chassis of the amp floating (not connected). This turns the amp chassis into an effective antenna. Connecting it to the auto body ground will turn the amp chassis back into a shield, which is what it should be.

Figure 4 shows how to bypass the alternator output. It's important to put the bypass capacitor as close as possible to the source of the interference. Make sure that the ground connection (the vehicle body is the place to use) to the capacitor is solid and clean. If you have an ohmmeter, measure the resistance between the capacitor and the vehicle body. It should be less than 0.3 ohm.

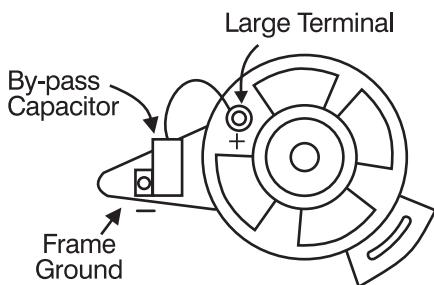


Figure 4. Bypassing the alternator output.

Grounding practices

CAUTION
Ground Isn't Ground!

Remember those words. Any time that you think that grounding is a trivial matter recite those three words.

The basic reason that we ground anything at all is to supply a negative return for the electric current that operates a device. If you're an auto maker, basically anything that is metal and somehow associated with the vehicle body is fair game. If you're a state-of-the-art autosound installer, that belief is the first and last mile on the road to ruin.

A second reason that things are grounded is so that their metal enclosures can act as a shield for incoming EMI. Remember...the metal enclosures only act as a shield when they are grounded. This helps keep portions of the circuitry that weren't designed to be radio receivers from becoming radio receivers.

Ground loops cause problems by allowing multiple paths into the grounding system. This wouldn't be such a problem if it were not for the finite and measurable resistance of the ground system. When you combine the multiple current paths into the ground system caused by the auto maker's indiscriminate definition of the word ground and the finite resistance of the ground system you get voltage drops. These voltage drops cause trouble when they get into an audio system via a ground loop. What happens is that the audio system tends to amplify any noise present in the ground system. The net result is noise.

Here's some (heh-heh) ground rules:

1. There should be one and only one path to the negative side of the vehicle electrical system. If you elect to use the vehicle body as this point, scrape the paint from under the contact point, and use a lockwasher on both sides of the terminal lug.

In extreme cases, you may need to run a heavy gauge wire to the battery's negative terminal. Alternatively, you could use the point where the battery negative hits the vehicle frame. Again, clean everything and use lockwashers. If the connection point is subject to vibration (like on the engine), then be sure to use stranded or braided wire (braided is better) and leave enough slack so that the entire length of wire can vibrate. This will help keep it from breaking.

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2. If you mount everything on a board, connect the chassis of each component to a good, solid electrical ground. The vehicle body is a good choice here because what you want is a good RF (radio frequency) ground. The wire running to the negative side of the electrical system has inductance which raises its impedance at high frequencies. In effect, at radio frequencies, the impedance could be high enough that the wire would look like an open circuit. Braided wire works best here because it has low inductance.
3. It's good insurance to use an ohmmeter to make sure that the chassis of each component isn't already tied to its internal electrical ground. Sometimes the case is tied to circuit ground through a low to moderate value resistor. If the case to negative wire resistance is greater than 10 ohms, then it's you can connect the unit's case to the auto body ground without causing a ground loop.
Some manufacturers put a switch on the unit to allow you to pick where the chassis is grounded. If you supply the connection to the chassis of the unit make sure that the switch doesn't supply one too.
4. Some premium connecting cables have oversized connectors. Make sure that the shell of the connector doesn't inadvertently contact the chassis of the unit that it is plugged in to. If this happens, you've got a ground loop on your hands.
5. When you think that you've got everything right, turn everything on, and disconnect the antenna and the negative connection to the vehicle's electrical system. If everything quits, you've got a single point ground.

Remember: **Ground isn't ground!**

Wiring Practices

After grounding, the rest is relatively easy. Here's a few hints:

- Avoid running audio wiring along (parallel to) with high-current power wiring. The improvement in noise pickup is proportional to the square of the distance between the wires. This is more important when applied to line level audio wiring rather than speaker wiring.
- For high-powered systems, run heavy gauge wires directly to the battery for the power amplifiers. How heavy? That depends on the distance of the run, and the current demands of the amplifiers. You can't err by making the wire too big.
- It may help to add an RF bypass capacitor at the amplifier end of the power cable to auto body ground. It may also help to add a second bypass capacitor from the positive side of the cable to the negative lead that runs back to the electrical system ground.
- Bad cases of alternator noise interference will probably require series chokes in the positive power lead into the system. It may be easier (economically as well as electrically) to filter each unit in the system separately than to try to find an interference choke with enough current capacity to handle an industrial-strength power amplifier.
- Don't use the auto body ground as the ground return for the speakers. They should connect to ground via the power amplifiers output connections.

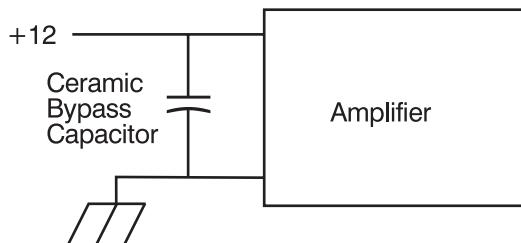


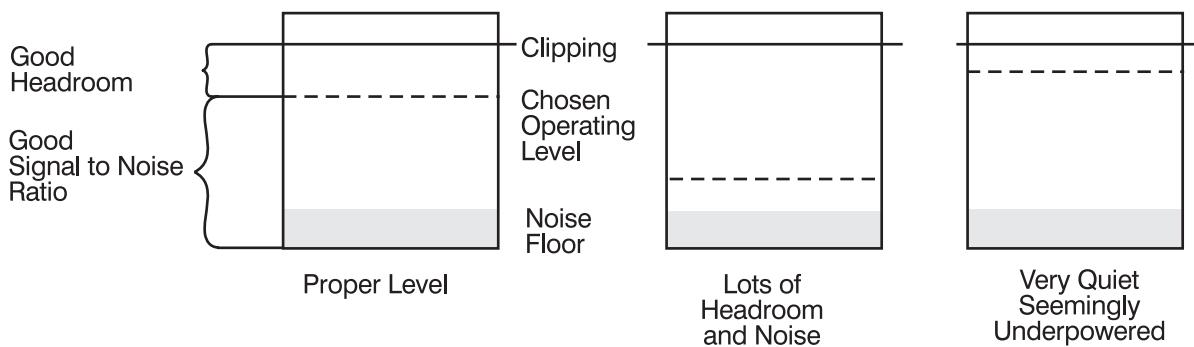
Figure 5. RF bypassing the power supply lines.

Level matching

Last but not least is level matching. I'm presenting this last because all the other aspects of the system must be right first. Level matching helps minimize hiss: the residual noise output of the head unit. Level matching can help make other noise sources (alternator noise, etc.) less evident by making the useful signal much louder than the noise. This is the reason for keeping the volume setting high, and the amplifier sensitivity low.

In many autosound systems, the manufacturers have provided level controls to allow the sensitivity of the unit to be adjusted to suit the requirements of the installation. Since there isn't much standardization within the autosound industry, such controls are both useful and necessary. As mentioned earlier, picking the proper operating level for a device gives you the best compromise between noise and headroom.

In the case of a head unit and a power amplifier, you want the output of the head unit to be high enough to still give reasonable headroom, while being as far above the noise floor as possible. From the amplifier's standpoint, the level control should be set so that the amplifier is just barely at clipping (or too loud, whichever comes first) at that point. Typically, this means a fairly high (75% rotation) volume control setting. Remember: even though the head unit's volume control is turned way up, you still get full power output out of the amplifiers once you match their sensitivity to the output level of the head unit.



There is another benefit of getting the highest possible operating level for the head unit: If noise is induced into the cable or wiring connecting the head unit and the power amplifier, the audio signal is subjectively much louder. This helps to make it more inaudible.

Here's a simple procedure:

1. Set the amplifier level control to minimum sensitivity. This is the setting where the volume is lowest.
2. Using either FM radio or a tape for a signal source, advance the volume control on the head unit until you hear distortion or reach 100% rotation. If you reach distortion before 100% rotation, reduce the setting of the control slightly until the distortion disappears.

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3. Now adjust the sensitivity control on the power amplifier until you hear it clipping, or the system is too loud.

Remember: you want as much signal going through the cable between the head unit and the power amplifier as possible.

Interfacing with internal power amplifiers

Sometimes you have no choice but to use an existing powered radio/head unit as the front end for a sound system. Although the speaker connections were originally meant to drive loudspeakers, there's no reason why they can't drive components that were originally meant to be used with an unpowered head unit. The biggest problem is simply one of signal levels.

Basically, a powered radio (I'm going to use the term "radio", but you can translate that to mean radio, cassette deck, or manufacturers installed stuff) is nothing more than a head unit with a lot of output capability (voltage drive capability). Don't confuse the fact that this thing was meant to drive loudspeakers (power) with its voltage output capability. Voltage and power are two different things.

Now there's two different types of radios we are dealing with...the so called "normal" ones with 3 to 5 watts output on a good day and the "high-powered" ones with 10-15 watts output. Basically, there's three ways to get high power when you've only got 14.4V to work with:

1. Use an output transformer to lower the effective impedance of the load. If you reduce the load impedance to around 1 ohm, you can get some pretty impressive output figures. Unfortunately, output transformers are large (if you want them to pass low frequencies) and expensive (if you want them to sound good). That precludes using them in a radio intended to be built into a dashboard.
2. Use a DC to DC inverter to raise the 14.4V to something better suited to getting more power into a 4 ohm load. Again, it's bulky and expensive. This sort of technology is better suited to being hidden in the trunk.
3. Use two amplifiers in "bridge" configuration. This is the infamous "floating output" connection. Figure 6 shows how it works. Basically, as amplifier 1's output is going positive, amplifier 2's output is going negative, by exactly the same amount. The net result is that the power supply voltage is doubled, which means four times the power into the same impedance. For example, if one amplifier would deliver 3.5 watts into a 4 ohm load, then two amplifiers in bridge connection would deliver 14 watts into the same 4 ohm load.

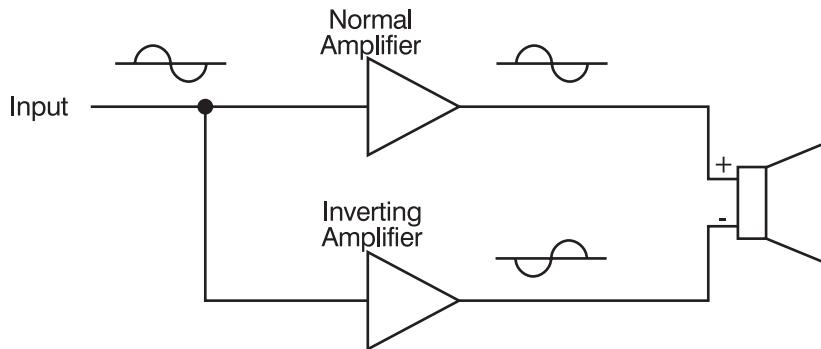


Figure 6. How bridged, floating outputs work.

Minimizing Noise in Autosound Systems

Connecting a normal (one side of the output is actually connected to ground somewhere in the system) radio to an equalizer or power amplifier is easy.

1. Somewhere near the radio, cut the wires short and splice them into a piece of shielded cable. Run the cable to the equalizer or amplifier and terminate it in a compatible connector. Be sure that the hot side of the radio output goes to the center wire of the shielded cable, and the ground side of the radio output goes to the shield of the shielded cable. Do the same when you install the plug at the other end.
2. Set the power amplifier or equalizer for minimum sensitivity (highest voltage required to drive it).
3. Connect the speakers to the amplifier.
4. Turn on everything and adjust the radio's volume until you can hear distortion. Back off the volume control until the distortion goes away.
5. Adjust the power amplifier's level control until the amplifier distorts, or the system gets too loud. If you are using an equalizer, use the equalizer's input level control for this adjustment, then adjust the power amplifier input level control so that it is compatible with the equalizer output.
6. What you are trying to do is set the gain controls so that the radio's amplifier clips at nearly the same time as the new external amplifier. If there is an equalizer in the system, then you adjust the radio till it barely distorts, and then adjust the equalizer's input level control to make this signal level palatable to the equalizer's circuitry. Once you've done this, you can ignore the fact that the radio has a power amplifier in it.

If the radio is a high-powered unit, then all you do is to use ONE of the two output leads (pick the ones that would have gone to the hot terminals of the speakers) and the system ground (not auto body) connection. Tape and insulate the other two wires. Now use the procedure above, beginning at Step 2.

Conclusion

We've covered a lot of ground in a short time. Some of the concepts presented may not be crystal clear the first time through. Take the time to read them through and attempt to understand them. Don't let the numbers scare you; you can skip them until you get deeper into the subject.

The subject of noise is not a simple one. There are many different noise sources, and perhaps twice as many cures. You can take a shotgun approach to the problem and perhaps be successful 50% of the time. The rest will require careful attention to detail as well as careful analysis of the problem.

In your customer's ears, anything that isn't music is probably noise. You, as the installer must be able to separate out the various noise sources and deal with each of them individually. Most wiring shortcuts end up costing you more in troubleshooting time than they're worth. Learning how to troubleshoot a noise problem is one of the more subtle things that a successful autosound installer needs to understand. Understand it, and in the end, you'll find that more of your systems work properly when they're first turned on. Isn't that what it's all about?

Remember:

- Ground isn't ground.
- Check for ground loops.
- Match signal levels between components.
- Observe good wiring practices.
- Know your noise sources.

Appendix A

Most noise problems with the AudioControl EQX Equalizer/Crossover and EQL Equalizer can be traced to improper level setting. The optimum signal level through the EQX or EQL is 1 volt. This is considerably higher than the output of most head units. Both units have adjustable gain input stages which boosts the input signal up to the 1 volt level. Since both units have bi-polar power supplies, they can operate with 1 volt signals without sacrificing headroom. Remember that peak output capability is directly related to power supply voltage. To be specific, the 9.5 volt maximum output level of the EQX or EQL gives them 19.5 dB of headroom above 1 volt. On the other end of things, the noise floor is 85.5 dB below 1 volt, giving a working signal-to-noise ratio of 85.5 dB.

Procedure for Head Units

1. Set the power amplifier to minimum sensitivity. This is the setting that produces the lowest volume (but not off).
2. Set the level controls on the EQX or EQL to the 12 o'clock position.
3. Set the EQ IN/OUT switch to the OUT position (eq defeat).
4. Set any tone controls on the head unit to their "FLAT" positions.
5. Using an FM radio station or a tape, adjust the volume control on the head unit until you hear audible distortion or reach 75% rotation. Be sure you have a good strong signal, or a cassette recorded at a high level. Compact discs work very well.
6. If you hear distortion, verify that it is not the power amplifier clipping by reducing the input level setting on the EQX or EQL. Of course, if the overall volume level isn't very loud (actually quiet), you can probably bet that it isn't the amplifier clipping.
7. If the volume control isn't at 75% rotation and you hear distortion, reduce its setting slightly until the distortion disappears.
8. Adjust the INPUT LEVEL controls on the EQX/EQL until the 3 dB HEADROOM INDICATOR just blinks. Back the controls off slightly. Both channels should be set to the same setting. If you can't get the HEADROOM INDICATOR to blink, leave both controls at maximum.
9. Set the head unit's volume control to minimum.
10. Set the power amplifier's level controls for .8V (800 mV) to 1V (1000 mV) sensitivity. Usually this is marked on the panel. If not, refer to the unit's owner's manual. Most currently available autosound power amplifiers have sensitivity ranges from .2V to 1.5V. If this is true for yours, then the proper setting (if it isn't marked) would be around half rotation.
11. If you have an EQX and you are bi-amplifying then skip the remainder of this procedure and pick up at the beginning of the special EQX procedure. If you have an EQX and are using FULL RANGE output, then the remainder of this procedure applies to setting the level of the EQX's FULL RANGE output.
12. Advance the head unit's volume control toward 75%. If the amplifiers clip, or if the system gets too loud, you are done. If you reach 75% without the amplifiers reaching clipping, or if the system isn't loud enough (and the amplifiers aren't clipping), increase the setting of the OUTPUT LEVEL adjustment on the EQL until the system is too loud, or you reach amplifier clipping, whichever happens first.
13. Set the EQ IN/OUT switch to the IN position. Now that your levels are matched, you can begin the equalization process.

Appendix B

Final Setup for the EQX

The initial part of the setup for the EQX is covered in the previous section.

1. Set the HIGH FREQUENCY and LOW FREQUENCY output controls of the EQX to 12 o'clock. Advance the head unit's volume control toward 75%. If the amplifiers clip, or if the system gets too loud, you are done. If you reach 75% without the amplifiers reaching clipping, or if the system isn't loud enough (and the amplifiers aren't clipping), increase the setting of the LOW FREQUENCY output control until the system is too loud, or you reach amplifier clipping, whichever happens first. Now readjust the high frequency output controls for a pleasing balance between the two parts (high and low, not left and right) using a variety of sources. If the sensitivities of your components are somewhat out of the ordinary (like tweeters less sensitive than woofers), then you may need to adjust the HIGH FREQUENCY output control instead. At least one of the two controls (per channel) should be set at or near 12 o'clock.
2. Now that you have established the high/low balance for your system and matched the input and output levels, press the IN/OUT button on the EQX to enable the equalizer section. Now you can begin the equalization process.

Appendix C

Procedure for Powered Radios

Using the EQX/EQL with head units with internal power amplifiers isn't all that difficult.

1. Determine whether the output is floating or grounded. Use an ohmmeter on both output wires (hot and ground) from each channel to the negative power connection. If the output is grounded, you will read a very low resistance (less than 1 ohm) between one of the output wires and the power supply negative lead.
2. If the output is floating, select the two wires that would have gone to the + terminals of the speakers. Insulate and store the other wires.
3. Connect the output wires to individual RCA plugs. Connect the shell of each RCA plug to the negative power supply wire. Twist the wires going to the RCA plugs. If the wires must be more than 1 foot long, splice them into shielded cables with RCA plugs attached. The shield of the cable goes to the negative power supply wire.
4. Set the power amplifier for .8V to 1V (800 mV to 1000 mV) sensitivity. If the amplifier isn't marked, and it's rated sensitivity is somewhere near 250 mV to 1.5V, then set the input level control to about 10 o'clock.
5. Set the OUTPUT LEVEL control on the EQX/EQL to the 12 o'clock setting.
6. Set the INPUT LEVEL control on the EQX/EQL to its minimum setting.
7. Using an FM radio station, a loud cassette, or a Compact Disc, adjust the volume control on the head unit until you hear distortion. This should be the point at which the head unit's power amplifier distorts. Reduce the volume control setting slightly.
8. Advance the setting of the EQX/EQL INPUT LEVEL control until the system is either too loud, or the amplifiers reach clipping, whichever happens first. If the 3 dB HEADROOM INDICATOR flashes, reduce the setting of the INPUT LEVEL controls slightly. Both controls should have equal settings.
9. If you have an EQX, disregard the remainder of this procedure and use the final setup procedure for the EQX that was described previously.
10. If the amplifiers are not clipping (and the system isn't loud enough), increase the settings of the OUTPUT LEVEL controls on the EQL until the amplifiers clip or the system is too loud.
11. Set the EQ IN/OUT switch to the IN position. Now that you have matched levels, you can begin the equalization process.

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